

**EXAMINING AGE-RELATED USE OF VISUAL IMAGERY SUBPROCESSES  
IN CHILDREN**

A Thesis

by

BRITTNEY DANIELLE OLIVER

Submitted to the Office of Graduate Studies of  
Texas A&M University  
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2011

Major Subject: Kinesiology

Examining Age-Related Use of Visual Imagery Subprocesses in Children

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Approved by:

Chair of Committee,	Carl Gabbard
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## **ABSTRACT**

Examining Age-Related Use of Visual Imagery Subprocesses in Children. (May 2011)

Brittney Danielle Oliver, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Carl Gabbard

This study examined the age-related ability of children (7 to 11 years) and adults to use visual imagery in tasks requiring the subprocesses of imagery generation, maintenance and inspection. Previous work had shown that young children's performance on imagery maintenance was comparable to other groups, but the level of development was inferior with tasks requiring imagery generation and inspection. We examined these findings using two newly created tasks (Line Direction and Clock Task) and one modified from previous work (Grid Task). Our data indicated that children's ability to use visual imagery generation, inspection, and maintenance was operable, but substantially below adult levels. In most cases, 7-year-olds displayed greater difficulty than their 9- and 11-year-old counterparts and adults with tasks involving response time. Our results suggest that whereas young children are capable of using the imagery subprocesses examined, at least one age-related constraint, especially with maintenance tasks, is short-term visual memory ability. We also recognize that other likely factors, especially with young children in response time situations, are attention and general information processing ability.

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## CHAPTER I

### INTRODUCTION

A review of mental imagery research, also referred to as mental simulation, suggests that these processes are fundamental to human information processing (see review by Bergen & Wheeler, 2010; Kosslyn, Thompson, & Ganis, 2006). According to Barsalou (2008), mental simulation is the internal enactment or reenactment of perceptual or motor experiences. Jeannerod (2001) contends that mental simulation is the keystone to cognition; simulation is the off-line recruitment of the same neural networks involved in perception and action. A review of brain research indicates that mental simulation is produced by brain structures specific to the relevant modality; visual imagery is produced through activation of visual areas (Kosslyn, Ganis, & Thompson, 2001), whereas, motor imagery uses motor areas, down to the specific regions that control simulated effectors (e.g., Ehrsson, Geyer, & Naito, 2003; Pelgrims, Andres, & Olivier, 2009). Adding to the significance of simulated processes in information processing, Kosslyn et al. (2006) indicate that mental imagery underscores memory, reasoning, and learning and *all* imagery allows us to generate specific predictions based upon past experience in regard to the imminent or distant future.

Whereas in recent years considerable attention has been drawn to motor (kinesthetic) imagery ability in children (Caeyenberghs, Tsoupas, Wilson, & Smits-Engelsman, 2009; Frick, Daum, Wilson, & Wilkening, 2009; Funk, Brugger, &



Wilkening, 2005; Gabbard, 2009; Molina, Tijus, & Jouen, 2008), much less is known about the developmental and age-related aspects of visual imagery, the focus of the present study.

The following provides a brief background of the key literature associated with this study's purpose.

### **Visual Imagery and Subprocesses**

Whereas motor imagery is typically described as a relatively 'unitary' process involving action (kinesthetic) stimulation, visual imagery has been differentiated into distinct representations and subprocesses; imagery generation, transformation, maintenance, and inspection (e.g., Kosslyn, Brunn, Cave, & Wallach, 1984; Kosslyn et al., 2004; Thompson, Slotnick, Burrage, & Kosslyn, 2009). For example, the versatility of visual imagery includes the ability to form (generate) images based on stored information, hold those images in short or long term memory (maintenance), mentally rotate images (transformation), and be able to interpret images (inspection).

Kosslyn et al. (1990) suggest that of the four components, image inspection and rotation are likely to use similar mechanisms which involve "kinetic imagery." The process of image inspection involves shifting one's attention over an object or scene while image rotation involves movement of the object itself. Debate continues regarding the mechanistic similarities between image generation and maintenance. Whereas image generation and maintenance are parts of the same imagery process, results from other studies indicate that image generation and maintenance are independent processes which

are carried out by distinct mechanisms (Cocude & Denis, 1986, 1988; Farah, 1989; Uhl et al., 1990).

According to Piaget and Inhelder (1971), younger children have difficulty in transforming imaged objects, that is, static images are visualized easier than those requiring image rotation or inspection. Thus, younger children should have more difficulty with image rotation and inspection tasks.

In summary, the discovery of visual imagery subprocesses is important because it reveals that not all of the components must be used for any given imagery task. For instance, an individual's ability to mentally inspect an object may be different from their ability to mentally maintain an object. Therefore, proficiency of the individual components of visual imagery varies from person to person and very likely differs with age (Kosslyn et al., 1990). It seems that further research regarding the independence and similarities of these subprocesses is needed.

### **Studies of Visual Imagery in Children**

In reference to the developmental literature, in one of the earliest studies conducted by Marmor (1975), participants were asked to determine whether drawings of panda bears in different orientations were the same or different. Results indicated that children as young as 5-year-olds were capable of using mental 'rotation'. Kosslyn and colleagues (1990) compared children (5-, 8-, 14 years) and adults on tasks requiring image generation, maintenance, inspection, and rotation. The researchers found no evidence that younger children have fewer processing components; however, younger children were less efficient at generating, inspection, and rotating images. Interestingly,

the single aspect that was similar across age groups was the ability to ‘maintain’ images in memory. In a later study by Funk et al. (2005), the researchers found that 5-year-olds were capable of using mental ‘rotation’ in making left–right decisions about two-dimensional objects; the task was to determine whether a car (rotated at different angles) would drive to the left or to the right. While examining the relationship between mental (visual and motor) imagery ability and motor ability in children aged 7 to 12 years, Caeyenberghs et al. (2009) found that visual imagery was reasonably well developed by 7 to 8 years. However, a limitation of that study was that the researchers only tested a single subprocess via letter ‘rotation’.

In summary, whereas there is reasonable body of evidence suggesting that children as young as 5-years of age are capable of mental rotation, information about the other aspects of visual imagery is less known.

### **Purpose**

With the aim of gaining more insight into the subprocesses associated with visual imagery ability in children, we compared children and adults on three tasks requiring imagery generation and / or maintenance, and inspection. Based on the findings of Kosslyn et al. (1990), the specific aspect of interest here was visual imagery maintenance, which we probed using a task created specifically for this experiment - Line Direction Task and an adaptation of the Grid Task used by Kosslyn et al. (1990). As noted earlier, with the Grid Task, Kosslyn and colleagues found performance similar across age groups. The third test, the Clock Task, also represents a new activity designed for this experiment with the aim of examining image generation and inspection.

Therefore, the intent of this study was to probe the age-related differences in the case of visual imagery subprocesses of image generation, maintenance, and inspection.

This study examined the following research question: Are there developmental differences in the use and activation of the visual imagery subprocesses of image maintenance, generation, and inspection?

## CHAPTER II

### THE STUDY

#### Method

##### *Participants*

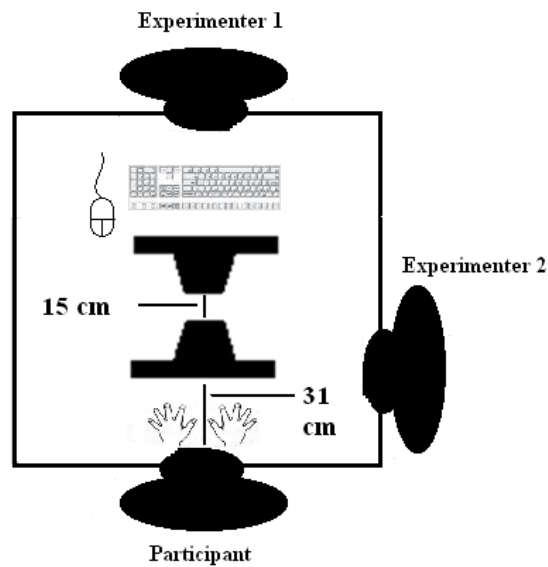
The study involved 54 participants representing four age groups: 7 years ( $n = 15$ ), 9 years ( $n = 13$ ), 11 years ( $n = 12$ ) and a group of adults, 19-23 years ( $n = 14$ ). The mean ages were 7.22, 8.67, 10.17, and 20.93 years, respectively. All participants were screened using a questionnaire (filled out by the parent for the children age groups) to ensure normal vision and that none have a history of past or present sensorimotor impairment. For the purposes of this study, only participants identified as strong right-handers via manual performance rather than questionnaire were selected. That is, those for whom all items scored in that lateral direction using the Lateral Preference Inventory (Coren, 1993) were included in the investigation. To qualify for the Clock Task, potential participants were screened for the ability to state accurate time of day. Participants were required to provide the correct time for three (out of 3) time presentations. This resulted in exclusion (for that task only) of six children from the 7-year-old group and one from the 9-year-old group. For the Line Direction Task, four children from the youngest group were not able to understand the instructions and were therefore excluded from that task.

##### *General Procedure*

Participants were tested individually in an isolated dimly lit room. The setup for two of the tasks (Clock and Grid) consisted of two interfaced computers (50.8 cm [20 in]

screens); 15 cm apart back to back, one facing the participant and the other the experimenter controlling stimuli presentation (see Figure 1). Participants were seated comfortably in an upright position facing the computer screen (approximately 31 cm away) with hands placed on the edge of the table. Height of the chair was adjusted to match participant's head height and top of the computer screen. Each of the two tasks required accuracy of response (yes or no) and response time. Data was collected for accuracy of response (yes or no) and response time. Response time was programmed via computer to begin with appearance of the experiment stimulus after the 'Get Ready' cue and completed by an experimenter via keypad (sitting adjacent to the participant) timed with the participant's 'yes' or 'no' response. This procedure was pilot-tested and determined favorable to experimenter control due to some inconsistency, especially with 7-year-olds, with remembering to coincide stopping the timer with their verbal response. Programming was designed using MatLab software.

For the Line Direction Task, participant and experimenter were seated side-by side in the middle of a table measuring 1.8 x 0.91 m [6 x 3 ft]. Each of the three imagery tasks was presented in counterbalanced order.

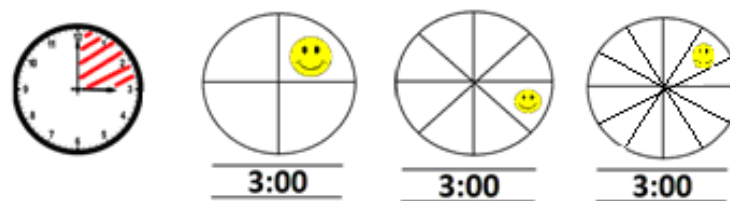


**Figure 1.** Sample procedural set-up for the Grid and Clock Tasks.

### *Task Description*

*Clock Task* (image generation and inspection). With this task, an image of a segmented 17.5 cm diameter circle appeared on the monitor. The number of segments in which the circle was broken into increased in number as task complexity increased: level one consisted of a circle with 4 segments, level two 8 segments, and level three 12 segments. The participant was asked to think of the circle as if it were a picture of a clock on which a certain time of day is displayed. The time (e.g., 3:00) that the participant was to imagine and generate was displayed underneath the segmented circle in each trial (see Figure 2). With each of the trials, a picture of a smiley face randomly appeared inside one of the segments of the circle; size of the smiley face decreased in proportion to the increase in number of segments (3 cm, 2.5 cm, and 1.5 cm,

respectively). At that point, the participant was required to imagine where the ‘hands of the clock’ would be and decide whether the smiley-face was positioned in the space between the ‘hands’ for that time. Each trial began with a ‘Get Ready’ visual cue lasting 2 s; this was presented at the beginning of the first trial and immediately after the participant’s trial response. A total of 15 trials will be given: 5 per level of complexity. Accuracy and response time were recorded. As noted earlier, this task was created and pilot-tested for this study.

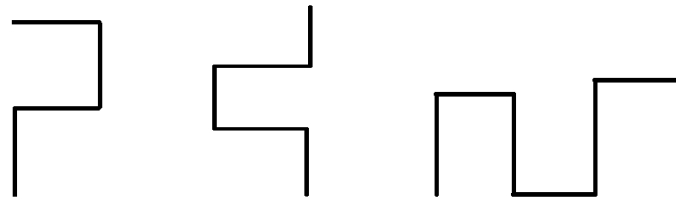


**Figure 2.** Sample stimuli for the Clock Task. First clock is an example of the area in which the smiley face is to fall for the response to be “yes” for 3:00. The next three circles are sample stimulus for the three levels.

*Line Direction Task* (image generation and maintenance). This task required the participant to reproduce a visual pattern consisting of a series of approximate 1-inch lines. At the start of the task, the participant was shown a picture of a vertical 1-inch; he or she began with this line for each trial. The experimenter gave directions, without executing any movement, to draw lines in a predetermined pattern (e.g., “right”, “left”, “up”, and “down”). After the completion of the experimenter’s directions, the participant was immediately given a ‘Now Draw’ cue requiring the participant to reproduce (from



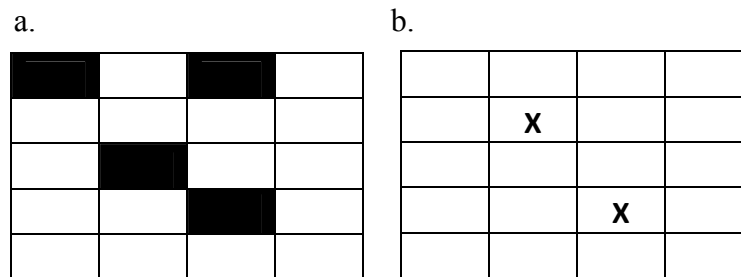
memory) the pattern as accurately as possible. There was no time limit for response – when the participant stated ‘Finished’, a new trial began. Participants received the same 9 patterns in three levels with 3 patterns in each level: level 1 consisted of 4 lines, the second level 5 lines and the third 6 lines (see Figure 3). To enhance use of imagery, the participant was asked to close his / her eyes and then to open them and draw what they had generated once all of the directions were given. The time it took to describe each task level increases approximately 1s per level: 10 s, 11 s, and 12 s, respective to level. Accuracy was determined by the ability to correctly replicate the general pattern without any line deviations - handwriting was no a key factor.



**Figure 3.** Sample stimuli for three different levels of the Line Direction Task.

*Grid Task* (image maintenance). Similar to a task described by Kosslyn et al. (1990) in their study of children, the Grid Task assesses visual short-term memory of participants. According to Kosslyn et al., in order to perform this task, images must be maintained and compared to new stimuli in the form of X'ed squares. The experimental setup consists of a grid of squares appearing on the computer monitor facing the participant. The first level, representing a relatively light level, consisted of a 5 x 4 grid

(23x 29 cm) displaying 20 squares; 4 of the square were shaded (see Figure 4a). This image appeared on the screen for 5 s, disappeared and then replaced with the same grid; however 2 X's were systematically positioned in two of the squares (see Figure 4b). The task was to determine whether the squares marked with the X corresponded to the shaded squares in the previous grid. The participant responded “yes” or “no”. The task was then repeated for the ‘heavier level’ condition comprising of a 7 x 5 grid (21 x 29 cm) (35 squares), 8 of which were shaded. After the 5 s delay, the new grid with 2 X's was displayed.



**Figure 4.** Samples of stimulus representation for the Grid Task.

#### *Treatment of the Data*

*Line Direction Task.* Total score was defined by the number of correct figures drawn by the participant out of the total number of figures (8). We calculated the percentage of the total score obtained by each participant to use as the dependent variable. This data were analyzed using a 4- [Age Group] way analysis of variance procedure, and if appropriate, *Tukey* post hoc analyses ( $p < .05$ ).

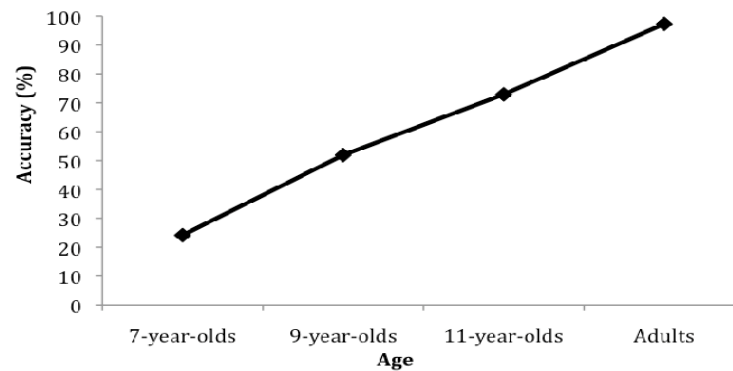
*Clock Task.* Two dependent variables were used: proportion of right answers (out of 5 trials) and response time, for each level of complexity (1, 2, and 3). These data were analyzed using a 4 (Age Group) x 3 (Level) repeated measures ANOVA procedure, and as appropriate, post hoc analyses.

*Grid Task.* Two dependent variables were used: proportion of right answers (out of 10 trials) and response time, for each level of the task (light/ heavy). These data were analyzed using a 4 (Age Group) x 2 (level) repeated measures ANOVA procedure, and as appropriate, post hoc analyses.

## **Results**

### *Task Results*

*Line Direction Task.* Figure 5 provides a graphic illustration of mean values by age. ANOVA results indicated that the proportion of correct responses by Age were significantly different,  $F(3, 50) = 25.69, p < .05, \eta^2 = .607$ . Mean values were: 7-year-olds ( $M = 24.16, SD = 25.64$ ), 9-year-olds ( $M = 51.92, SD = 28.34$ ), 11-year-olds ( $M = 72.92, SD = 26.02$ ), and adults ( $M = 97.32, SD = 7.23$ ). Tukey post-hoc comparisons showed that the 7-year-olds and the adults were different than the other groups. Both the 9- and 11-year-olds did not differ from each other, but were different than the 7-year-olds and the adult age group.



**Figure 5.** Graphic illustration for percent correct responses for the Line Direction Task.

*Clock Task.* Table 1 presents mean values for percentage of correct of responses and response time. For proportion of correct answers, ANOVA results indicated that Age and Level were not significant, nor was there any interaction. For response time, we found that Age  $F(2, 86) = 4, 31, p < .05, \eta^2 = .091$  and Level  $F(3, 43) = 8.82, p < .05, \eta^2 = .381$  were significant, however there was no interaction. Tukey post-hoc comparisons showed that 7-year-olds differed from the 9-year-olds and adults, but not from the 11-year-olds. The adult group differed from all groups, except 9-year-olds. The 9- and 11-year-old groups were not different from each other.

**Table 1.** Mean values per level for the Clock Task.

	Level			<i>Mean (<math>\pm</math> SD)</i>
	1	2	3	
	<i>M (<math>\pm</math> SD)</i>	<i>M (<math>\pm</math> SD)</i>	<i>M (<math>\pm</math> SD)</i>	
Percent Correct				
7 year-olds	86.6(17.30)	77.7(18.50)	73.3(24.40)	79.2 (11.20)
9 year-olds	85.0(15.00)	88.3(15.80)	78.3(15.80)	83.8 (9.62)
11 year-olds	83.3(14.30)	83.3(18.70)	80.0(22.50)	82.2 (11.10)
Adult	91.4(10.20)	91.4(15.10)	87.1(25.20)	90.0 (15.80)
Response time				
7 year-olds	7.77(3.29)	7.11(2.67)	9.54(3.78)	8.14 (2.85)
9 year-olds	5.04(1.34)	5.42(1.95)	5.21(1.51)	5.23 (1.33)
11 year-olds	4.99(2.14)	6.29(3.06)	6.34(3.60)	5.87 (2.58)
Adult	3.45(9.84)	3.74(1.51)	3.81(2.08)	3.67 (1.36)

*Grid Task.* Mean values for percentage of correct responses and response times are shown in Table 2. For proportion of correct answers, ANOVA results indicated that Level and Age were significant and there was an interaction,  $F(1, 10) = 17.8, p < .05, \eta^2 = .263$ ;  $F(3.50) = 3.90, p < .05, \eta^2 = .190$  and  $F(3.50) = 6.32, p < .05, \eta^2 = .275$ , respectively. Simple main effect analysis showed that Level (light/heavy) was different for the 9-, and 11-year-olds and adults. In addition, overall scores for the heavy level were significantly lower than light condition responses. For response time, there was an Age effect and interaction,  $F(3.50) = 10.71, p < .05, \eta^2 = .391$  and  $F(3.50) = 8.74, p <$

.05,  $\eta^2 = .344$ , respectively. Simple main effect analysis showed that Level was different for the 7- and 11-year-olds and adults.

**Table 2.** Mean values per level for the Grid Task.

	Level		Mean ( $\pm$ <i>SD</i> )
	Light <i>M</i> ( $\pm$ <i>SD</i> )	Heavy <i>M</i> ( $\pm$ <i>SD</i> )	
Percent Correct			
7 year-olds	78.0(19.00)	82.6(10.30)	80.3 (12.70)
9 year-olds	90.0(10.00)	78.4(10.60)	84.2 (8.60)
11 year-olds	94.1(7.90)	85.8(12.40)	90.0 (10.00)
Adult	97.8(4.20)	82.9(10.00)	91.4 (6.33)
Response time			
7 year-olds	4.56(1.92)	3.88(1.59)	4.22 (1.65)
9 year-olds	3.02(0.49)	2.76(0.60)	2.89 (0.48)
11 year-olds	2.87(0.56)	3.50(0.97)	3.19 (0.66)
Adult	1.88(0.28)	2.51(0.50)	2.20 (0.34)

## Discussion

With the present study, we compared children (aged 7 to 11 years) and adults on their ability to generate, maintain, and inspect visual images. Of specific interest, based on the findings of Kosslyn et al. (1990), was visual imagery maintenance; in their study no age differences for children were found with a task requiring this subprocess. Such tasks, including those used here and the Grid test described by Kosslyn and colleagues required use of *visual short-term memory*. In general, the literature supports the

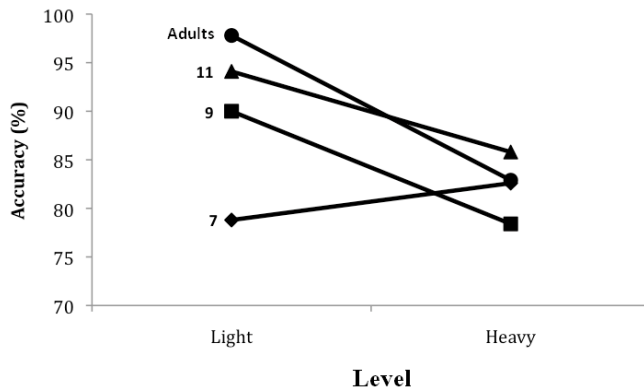
observation that performance on visual memory tasks improves with age (e.g., Hamilton, Coates, & Heffernan, 2003; Wilson, Scott, & Power, 1987; Swanson, 1996). More specific to visual short-term memory, Ang and Lee (2010) observed that on a Visual Patterns Test, similar to the Grid Task described in our study, 11-year-olds performed better than 8-year-olds. Also using a similar task in which participants aged 5- to 11 years and adults were asked to remember missing information in a square matrix, Wilson and colleagues (1987) found that older children outperformed younger children with adult levels of performance being reached by 11 years of age. Although others have shown no age differences with other types of short-term retention tasks (Fahle & Daum, 1997), it seemed reasonable to expect age differences in the present study.

Based on results from the Line Direction and Grid Tasks, our data supports the general observation that younger children have more difficulty with visual imagery maintenance - imaging tasks requiring short term memory. Of all the tasks used in this study, the one showing the clearest age effect was Line Direction; mean values for percent correct were 24, 52, 72, and 97, respectively (see Figure 5). Given that the 11-year-olds were different than the adults, suggests that additional development occurs after 11 years.

Overall results for the Grid Task, in reference to proportion of correct responses, indicated the expected Level effect with the heavier condition being significantly more difficult than the lighter level (see Figure 6a). Interestingly, this was evident for all groups except the 7-year-olds. We can only speculate that both conditions were equally difficult for this group. An important point is that the 7-year-olds demonstrated good

accuracy, as evidenced by averaging 80 percent correct across conditions. As a side note, average percentage correct by the older groups was 84, 90, and 91 percent, respectively. In reference to response time, there was a distinct difference between the light and heavy level for the 7- and 11-year-olds and the adults. An interesting observation is that the 7-year-olds performed faster in the heavy level (not expected), while the 11-year-olds and adults performed slower in the heavy level, as expected (see Figure 6b). Speculatively, practice during the light level, always presented first, appears to have aided the younger group in the subsequent condition; practice that apparently produced no overall performance benefits for the 11-year-olds and adults.

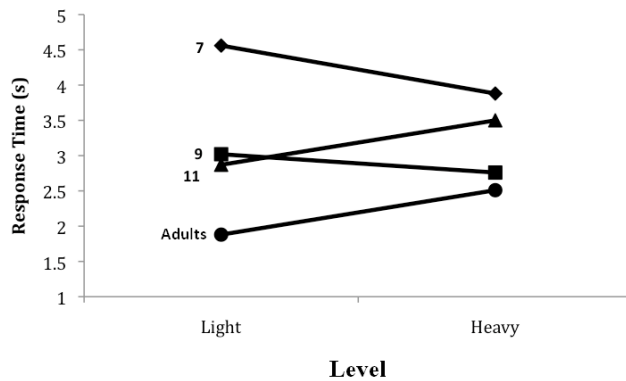
a.



**Figure 6.** Graphic illustration for a) proportion of correct answers and b) speed of response for the Grid Task.



b.



**Figure 6.** Continued.

Compared to Kosslyn and colleagues (1990) that reported no group differences in image maintenance (using a Grid Task), our findings in view of the two tasks used, indicate a significant age-related effect. In both the Grid and Line Direction Tasks, substantial development appears to differentiate age groups; this is most evident when comparing 7-year-olds and adults.

The Clock Task was developed specifically for this study with the aim of examining image generation and inspection, subprocesses that Kosslyn and colleagues (1990) reported presented greater difficulty for younger compared to older children. Whereas our results indicated no age-related differences for accuracy, we observed an effect for response time. As a general observation for speed, 7-year-olds and adults were distinctive from the other groups that were similar to each other. Furthermore, 7-year-olds displayed much more difficulty with the task, especially in the level 3 condition. Mean response times across conditions for 7-year-olds and adults were 8.14 s and 3.67 s, respectively. In essence, these results are supportive of Kosslyn et al. by showing age-

related differences in visual imagery generation and inspection. However, we find it relevant to differentiate aspects of the task. With accuracy, the 7-year-old's responses for 'generating' the hands of a clock to accurately determine placement of the smiley-face, were comparable to the other groups. Task age differences were reflected in response time with the 7-year-olds, whose response times were significantly greater than the older age groups. Based on the methodology of the task, we believe that while accuracy was more reflective of image generation ability, response time was a better indicator for image inspection ability. Therefore, it seems that children did have a more difficult time in inspecting and shifting their attention across the imaged clock. However, there is a reasonable argument that the combination of accuracy with speed, as displayed by the adults, is a better indicator of development.

Considering age-related ability with use of all three tasks, a few general observations are worth noting. First of all, there was a clear differentiation between the 7-year-olds and adults. Specifically, the 7-year-olds were outperformed by their older counterparts on tasks requiring visual imagery maintenance (Line Direction and Grid task) and response time in the Clock Task (image inspection). From another view, we analyzed the data combining the three younger groups and compared the values to the adults. With each task, considering accuracy and response time, we found a group (age) effect favoring the adults;  $p$  values ranged from 0.04 [percent correct / Clock Task] – 0.0001 [Line Direction Task].

### *Brain Development and Behavior*

In reference to brain development and behavior, these data offer comment on two aspects of mental imagery, that is, the maturation of the *parietal* and *prefrontal cortical* regions. Work with typically developing children and adults suggests that there is a close link between development of the *parietal cortex* and the ability to formulate internal models associated with imagery; suggesting that both are refined through the adolescent years (e.g., Blakemore & Sirigu, 2003; Choudhury, Charman, Bird, & Blakemore, 2007; Gerardin et al., 2000; Koscik, O’Leary, Moser, Andreasen, & Nopoulos, 2009; Lacourse, Orr, Cramer, & Cohen, 2005; Skoura et al., 2009). Another facet associated with the cognitive aspects of mental representation is development of the *prefrontal cortex* (e.g., Diamond, 2002; Skoura et al., 2009). Previous work indicates a strong correlation between the maturation of this cognitive structure and refinement of visuo-spatial working memory (Klingberg, 2006). Subsequently, our data is explained and supported by these developmental trends of cognitive maturation, particularly as seen in the Line Direction Task. As mentioned earlier, previous work has shown that the emergence of imagery, at least for mental rotation, emerges by age 5 (Caeyenberghs et al., 2009; Funk et al., 2005; Kosslyn et al., 1990). Our data for 7-year-olds, with some being as young as 6 years, supports these general observations.

Our tasks of visual imagery maintenance required use of visual short-term memory, which arguably is closely associated with working memory. The concept of working memory suggests that a dedicated system maintains and stores information in the short term, and that this system underlies human thought processes (Baddeley, 2003).

In addition, a relevant aspect of working memory, especially with younger children, is that this ability is displayed in the face of concurrent distraction. The preponderance of behavioral work clearly shows that this important ability improves during childhood and adolescence (e.g., Barrouillet, Gavens, Vergauwe, Gaillard, & Camos, 2009; Bayliss, Jarrold, Baddeley, Gunn, & Light, 2005; Swanson, 2008). Extensive reviews of neuroimaging studies of the developmental nature of working memory indicate an interesting and rather complementary link to brain mechanisms underlying imagery; that is, development of *prefrontal* and *parietal* cortex regions (Casey, Tottenham, Liston, & Durston, 2005; Geier, Garver, Terwilliger, & Luna, 2009; Klingberg, 2006; Klingberg, Forssberg, & Westerberg, 2002). For example, Klingberg et al. (2002) using fMRI with children aged 9-18, found that older children showed higher activation in frontal and parietal regions during the performance of working memory tasks. Working with children aged 8-12 and adults, Geier et al. (2009) observed that whereas all age groups recruited a common network of brain maps while performing memory tasks, including frontal and parietal regions, adults were active in the posterior parietal cortex, whereas children and adolescents recruited a considerably more extensive distributed circuitry. The researchers concluded that brain processes supporting basic aspects of working memory are established by childhood. However, refinement in short-term (working) memory continues through adolescence; a statement that our data supports.

In summary, our results indicate that children's ability to use visual imagery generation, maintenance, and inspection is operable by 7 years, but substantially below adult levels. In most cases, 7-year-olds displayed greater difficulty than their 9- and 11-

year-old counterparts. This observation was especially evident with tasks that required a speedy response, which based on the developmental literature, was not unexpected. In regard to visual imagery maintenance, unlike Kosslyn et al. (1990), we found that whereas the youngest group was capable of performing the Grid Task, their performance was substantially below older groups. This finding was most evident from results of the Line Direction Task indicating clear differences across age groups. From these results we conclude that although young children are capable, as Kosslyn and colleagues found, of displaying visual imagery maintenance, at least one age-related constraint is short-term visual memory ability. We also recognize that other likely factors, especially with young children in response time situations are attention and general information processing ability.

## **CHAPTER III**

### **CONCLUSIONS AND RECOMMENDATIONS**

#### **Conclusions**

With the present study, we compared children (aged 7- to 11 years) and adults on their ability to generate, maintain, and inspect visual images. Of specific interest, based on the findings of Kosslyn et al. (1990), was visual imagery maintenance. Our results indicate that children's ability to use visual imagery generation, maintenance, and inspection is operable by 7 years. However, although young children are capable, at least one age-related constraint is short-term visual memory ability.

#### **Future Research**

Obviously, further examination of the age-related differences of visual imagery ability should be conducted. The present study suggests that there are age-related differences in the information processing components of visual imagery, namely image generation, maintenance, and inspection. Although use of the new paradigms (Clock and Line Direction) was successful, refinement of these tasks could allow for further examination of image generation, maintenance, and inspection.

Also of future interest is to examine the possible association between visual imagery, motor imagery and motor ability. Previous studies have reported a correlation between motor imagery to the action of a movement and visual imagery to perception (Sharma, Jones, Carpenter, & Baron, 2008; Young, Pratt, & Chau, 2009; review by Borst & Kosslyn, 2008). Based on these findings, it seems reasonable to conclude that both would play important roles in action planning. However, previous research

addressing the association between visual imagery and motor ability, Caeyenberghs et al., 2009, did not find a link between the two. From our perspective this seems somewhat surprising given that motor planning and execution are highly influenced by visual (spatial) information (Fourkas et al., 2006).

Further investigation should also aim to complement the developmental literature which links visual imagery with cognitive function.

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